CALIFORNIA WATER RESEARCH

The Delta Ecosystem as a Dynamic System, Water Supply Assumptions in Water Rights Decisions 990 and 1275, Summer and Early Fall Delta Flows, and Climate Change Impacts on the Delta

Comments for Second State Water Resources Control Board Workshop
Bay-Delta Fisheries Resources

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The Delta Ecosystem as a Dynamic System

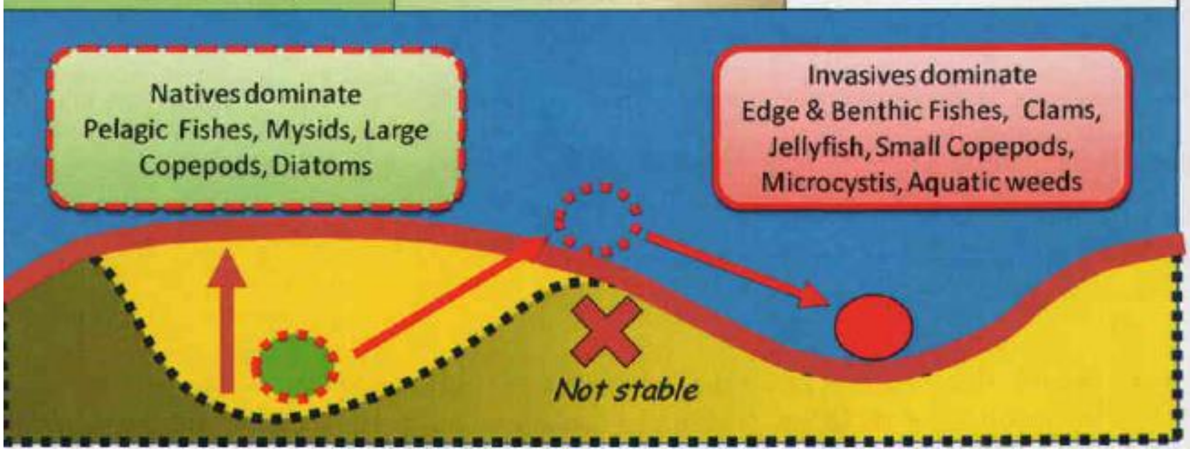
The State Water Resources Control Board is faced with the task of revising the Bay Delta Plan after the Pelagic Organism Decline and the collapse of populations of many native fish species which were formerly abundant in the estuary. It is clear that these populations are on the edge of extinction. The current proposal by federal and state agencies is to use adaptive management to set flow critiera to protect the public trust, including decision trees and further ecosystem studies.

However, it must be understood that this approach to use adaptive management to set flow criteria is not new. In essence, prior decisions by the State Water Resources Control Board (originally the State Water Rights Board) resolved conflicts about water supply for diversions by the state and federal water projects by approving the requested maximum diversions and setting limits related to salinity and fisheries resources, requiring monitoring, suggesting further studies, and retaining continuing jurisdiction. This has effectively been a five decade long adaptive management program.

Unfortunately, the criteria used for adaptive management of ecosystem flows have not been sufficiently protective of the Delta estuary or of San Francisco Bay. The result has been a decades long decline and collapse of native species of fish in the Delta, and a substantial decline in fish populations in the Bay. In the 1980s, the concerns were that populations of pelagic species of fish in the Delta had been reduced by 70%. By the 1990s, the concern was that some formerly abundant species had been pushed to the brink of extinction. In the 2000s, the concern was that populations of many species of fish in the Delta, that had formerly occupied a huge range of ecological niches, all collapsed simultaneously.

It is clear that the Delta ecosystem is far into a new regime. (See diagram below by Randy Baxter.)

Old Regime	Environmental Drivers	New Regime
Variable, High	Outflow	*Variable, Lower*
To the west, Variable	Salinity gradient	*To the east, Constricted*
Complex, Variable	Landscape	*Simplified, Rigid*
Low, Variable	Temperature	*High, Uniform*
High, Variable	Turbidity	*Low, Less variable*
High P, low N	Nutrients	*Low P, High N (NH_4+)*
Few, Low	Contaminants	*Many, High*
Predation, Fishing	"Harvest"	*Predation and Entrainment*



Regime shift model from Baxter, 2010, as reproduced in "Adaptive Management for Fall Outflow for Delta Smelt Protection and Water Supply Reliability", USBR 2011. Original Caption: "The ecological regime shift in the Delta results from changes in (slow) environmental drivers that lead to profoundly altered biological communities and, as soon as an unstable threshold region is passed a, new relatively stable ecosystem regime."

Over the long term, native species are declining or vanishing and invasive species are increasing at all levels, and the total biomass, both of the Delta and of San Francisco Bay ecosystems, is down significantly. For this reason, any ruling by the State Water Resources Control Board on adaptive management of water exports needs to explicitly consider the issue of ecosystem regimes and long term ecosystem stability. There also needs to be explicit consideration of upper limits on exports of unstored water needed to keep healthy populations of native fish.

In particular, the current permits for the State Water Project and Central Valley Project allow exports of very large amounts of unstored water from the Sacramento River and the Delta. The right to export this water is junior to the needs of the areas of origin. Therefore it needs to be subject to limits which are sufficiently protective of area of origin beneficial uses, including both fishery needs and local water quality needs.

For fishery needs, the public trust requires a management scheme where populations of aquatic species at different trophic levels are maintained within reasonably stable ranges. In addition, the target median population size for all species needs to be sufficiently large for the population to survive forseeable natural events. California has a huge natural variation in precipitation and runoff, that produces large natural variations in populations of aquatic species, and creates huge stresses during dry and critically dry years. Climate change is likely to increase these stresses in a myriad of ways, including reduction in runoff and an increasing frequency of dry and critically dry years, increased water and air temperatures, and changes in ocean conditions.

For this reason, the State Water Resources Control Board must significantly constrain exports of unstored water. Over the long run, it is simply not possible to adaptively manage populations of fish in an extinction spiral. To protect the public trust, the State Water Resources Control Board needs to set a range of exports of unstored water where the center of the range leaves enough water in the estuary to sustain robust, healthy populations of native fish, as well as to maintain water quality in the face of existing streams of contaminants.

Water Supply Assumptions in State Water Rights Board Decisions 990 and 1275

One of the key issues with the original permitting decisions by the State Water Rights Board was the lack of knowledge of hydrology and ecosystem needs. But even within that limited understanding , it became clear in the hearings for Decision 990 in 1959 and 1960 that there were significant conflicts between the assumed water supplies for the U.S. Bureau of Reclamation's applications for diversions from the Sacramento River and Delta, and the application of the California Department of Water Resources for diversions in the Delta.

In particular, at the November, 1959 hearing, became clear that the Bureau of Reclamation water supply study for the Central Valley Project diversions included the "entire flow of the Feather River" (Decision 990, p. 58). The hearing was recessed at the request of the state's attorney. During the following months. The Department of Water Resources and the Bureau of Reclamation worked out the first Coordinated Operating Agreement. In Article 12, the parties agreed to divide unappropriated water in the Delta in the ratio of basis of total diversions under applications permits, which were then 8,300,000 acre feet per year for the Bureau, to 5,260,000 acre feet per year for the Department of Water Resources, and to similarly allocate any shortages.[1] The Board decided that this was sufficient to issue the permits for the Bureau of Reclamation diversions.

The Board did note that "the variances between the Bureau's Central Valley Project and the Department's Feather River Project of 1951 and the plans presented at the hearing, involving no more water than was available in 1951 (except for the Trinity River diversion) poses a problem that cannot be solved by the Board. All it can do is maintain continuing jurisdiction until the Department receives its permits for the

[1] State Water Board, Decision 990, p. 59 Available at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d0950_d0999/wrd990.pdf

State Water Plan and has arrived at an operational agreement with the Bureau as proposed in the testimony of the Director of the Department."[2]

There were also issues in that no explicit reservation was made for the needs of water users in the Delta. The end result was that the permits which were approved for the Bureau of Reclamation relied on water supplies that were double-counted, and allowed export of water needed for the areas of origin.

These problems were further exacerbated by Decision 1275 in 1967, when the permits were issued for the California Department of Water Resources diversions in the Delta. A joint water rights investigation by the Bureau of Reclamation and the Department of Water Resources showed that there was likely too little water in the Delta for the State Water Project to divert any more water than the yield of Oroville reservoir. The Department of Water Resources produced studies showing that with an extra 900,000 af/year of water from the proposed Dos Rios Dam on the Eel River to supplement flows in the Sacramento River, that there would be enough water for the proposed diversions. The State Water Resources Board granted the diversion permit in the Delta based on these studies.

As we all know, by 1967, the construction of the proposed dam on the Eel River had become hugely controversial. In 1968, Governor Reagan intervened to mandate the development of alternatives. In 1972, the state legislature designated the Eel River as a Wild and Scenic River, as well as portions of the Klamath, Smith, and Trinity rivers. The Eel and undeveloped portions of the Trinity Rivers were designated federal Wild and Scenic Rivers in 1981.

The end result was that the upstream water supply for the permits issued by the SWRB for diversions in the Sacramento River and Delta was been short by millions of acre feet per year for the last five decades. As a result, there has been increasing reliance on export of unstored flows in the Delta, which has been very detrimental to fish populations.

State Water Rights Boards Decisions about availability of unstored water for export in summer and early fall

Decision 990 also explicitly considered the availability of water for export in the summer and early fall. The Bureau of Reclamation, the Department of Water Resources, and the Sacramento River and Delta Water Association produced studies of the existing diversions along the river. Page 28 of D990 describes the studies:

> In an effort to reach an agreement on existing water rights along the Sacramento River and in the Delta, the Bureau, the Department and the Sacramento River and Delta Water Association (hereinafter referred to as Association) entered into a cooperative study program. For the purposes of the these studies the engineers for each agency agreed upon certain assumptions with respect to hydrologic conditions and water rights. The final report acknowledged these assumptions, particularly with respect to water rights, may differ considerably from the rights as may be determined by a court of law. The results of these studies are presented in "Report on 1956 Cooperative Study Program" (USBR 107)

The study is referenced with respect to diversions:

[2] Ibid., p. 62

> With respect to the availability of water along the Sacramento River from Shasta Dam to the Delta and in the channels of the Delta, Study C-2BR indicates that no water is available during August and only infrequently available during July. Study C-650D indicates that September is also a month of questionable supply (USBR 139 and SRDWA 39).

This was true even though the studies relied on methods of estimating pre-existing diversions that were fairly incomplete, as well as completely outdated assumptions about needed Delta outflows. The studies assumed minimum Delta outflows of only 3,300 cfs in all months, and some of them assumed minimum Delta outflows of only 2,000 cfs.

D990 states that other evidence was presented by the Bureau of Reclamation and the Department of Water Resources about return flows:

> However, the Bureau presented evidence that because of return flows from applied Project water, there will be unappropriated water available in various reaches of the River below Keswick Dam and in the Delta year-round. This evidence is corroborated by testimony submitted by the Department (RT 10928-30).

This newly presented evidence likely double-counted the return flows, since the original 1956 Cooperative Study Program report included generous estimations of return flows in its calculations of water available for diversions. However, the State Water Rights Board allowed these estimates:

> There is no doubt that Project water applied to lands which drain into channels tributary to the Delta will provide additional return flows, but the quantities cannot be predicted with any degree of accuracy (RT 10972-75). Return flows from applied Project water will enter the Sacramento River at various points below Keswick Dam (USBR 164). It appears proper, therefore, to allow a year-round direct diversion season at points below Shasta Dam as requested by the Bureau.

But the Board continued:

> Any necessary reduction in the season can be made at the time of licensing when the project is fully developed and the extent of return flow can be more accurately determined.

Tables B through E, reproduced at the end of this report, show an average of the amounts available in study C-2BR and study C-650D, for pre-1927 appropriative and other rights, for pre-1938 appropriative and other rights, and for pre-1954&1955 appropriative and other rights.

The table below is produced from the averages for pre-1938 and other rights. It averages amounts available in Wet, Above Normal, Below Normal, Dry and Critically Dry years. It shows water available in July only in wet years, in August in no years, and very little available in September.

Year Type	Months of diversion							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Wet	4435	3914	2396	396	5	119	338	11603
AN	3644	1741	392	0	0	101	280	6157
BN	3003	2586	1262	8	0	74	296	7229
Dry	1795	1249	434	25	0	32	195	3730
Critical	562	355	200	0	0	9	92	1218

Decision 1275, approved by the Board in 1967, originally excluded July, August, and September from the allowed season of diversion for the State Water Project. Decision D1291 discusses the reasons:

> Decision D 1275 excluded July, August, and September from the authorized seasons of diversion from the Delta. The reason for excluding these months, discussed in the decision beginning on page 26, was that the studies introduced by the Department at the hearing (Exh. 72 and related exhibits) showed that unappropriated water would have been available in the Delta during these months in only a few years during the 30-year period of study and then only in small quantities.
>
> The Department contended in its petition that greater quantities of unappropriated water than were indicated by its previous studies will be available in the Delta for several years because the actual in-basin use of water will be less than the assumed in-basin rights due to the fact that some rights are still in a development period and all in-basin rights will not be utilized simultaneously at maximum rates.
>
> The Department's exhibits and testimony demonstrated that for several years substantial quantities of unappropriated water will probably occur in the Delta during July, August, and September that were not indicated by the evidence which was the basis for deleting these months from the seasons of diversion in Decision D 1275.

The Department of Water Resources produced the following table of water available for export in five of the 15 years between 1952 and 1967.

	July	August	September
1952	985	296	441
1956	410	250	568
1958	632	411	693
1965	252	340	606
1967	1,358		

These numbers were based on new assumptions about consumptive use in the Delta which were never checked. The State Water Board decision only stated that, "the magnitude of the quantities assures that there will be substantial water available in the Delta with an average frequency of one year in three even if the assumptions are in error by relatively large percentages."

On the basis of this rather speculative math, the State Water Rights Board allowed diversions of unstored water by DWR during the months of July, August, and September, as well as the U.S. Bureau of Reclamation.

We now have a much better knowledge of hydrology in the Delta, and there are sophisticated computer models of Delta flows. These numbers have never been compared with numbers from Dayflow, and should be.

Shifts in Precipitation in Delta Watersheds

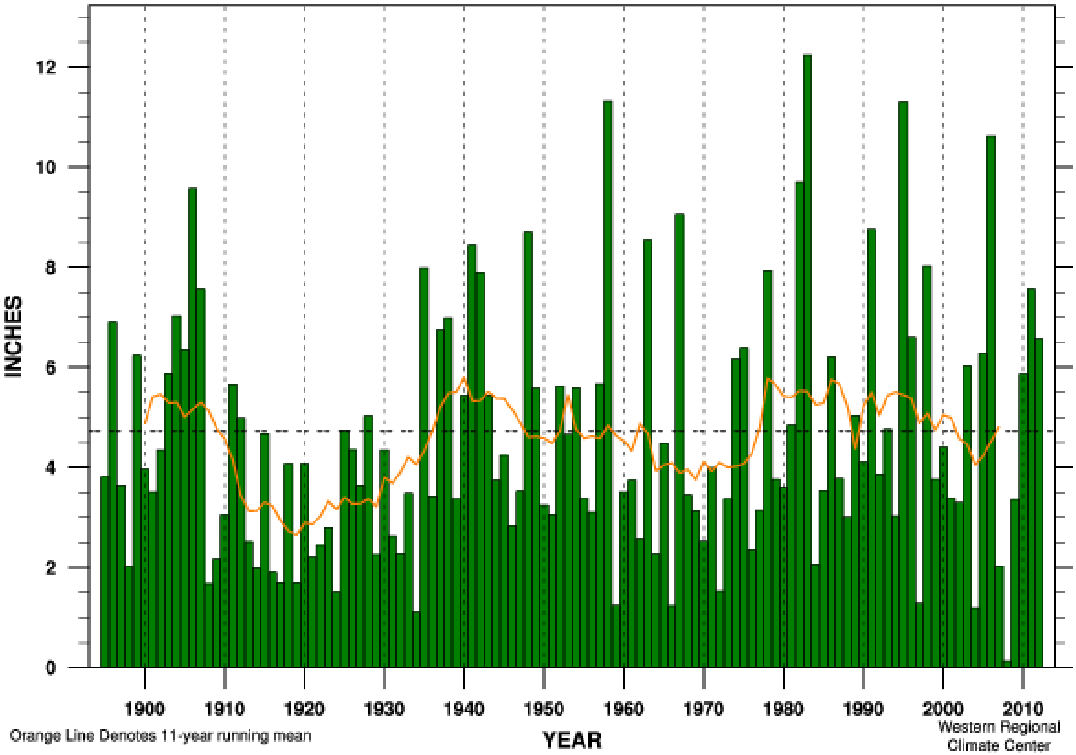
The charts below, from the Western Regional Climate Center, show shifts in precipitation in the Sacramento-Delta region. From 1975 to the present, there is a reduction in precipitation in the spring and fall, and an increase in the winter. As noted by Killam and Bui et. al., examination of regional data shows similar seasonal trends throught the state, including the Sierras [3],[4] The decreases in precipitation and shifts in runoff exacerbate impacts of water diversions by reducing Delta inflows and outflows in the spring, summer, and fall.

[3] Killam, D., A. Bui, S. LaDochy, P. Ramirez, W. Patzert and J. Willis. 2011. Precipitation trends in California: Northern and central regions wetter, southern regions drier. Unpublished. Cited in Temperature and precipitation trends in California: Global warming and Pacific Ocean influences, LaDochy and Ramirez et. al. (See reference 20.)

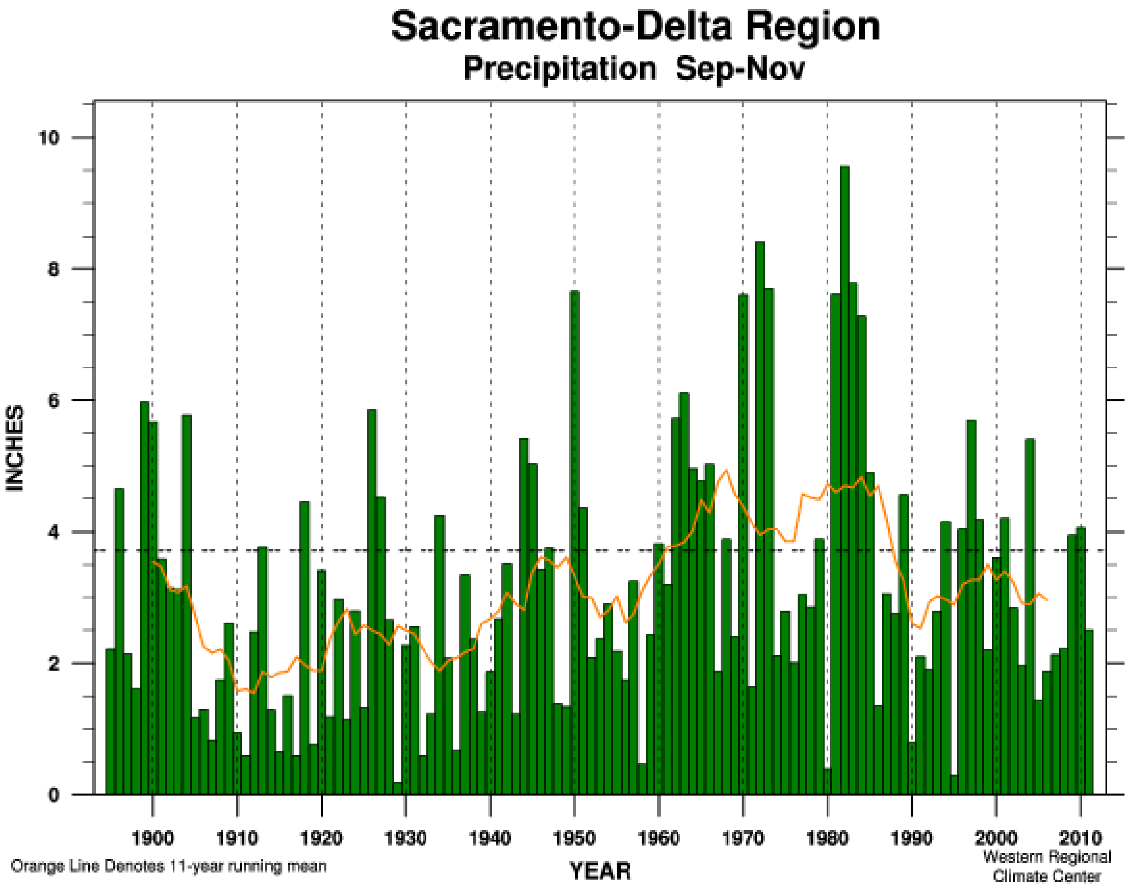
[4] Regional precipitation data with linear trends also available from Western Regional Climate Center, California Climate Tracker. Available at http://www.wrcc.dri.edu/monitor/cal-mon/frames_version.html

Sacramento-Delta Region

Precipitation Mar-May



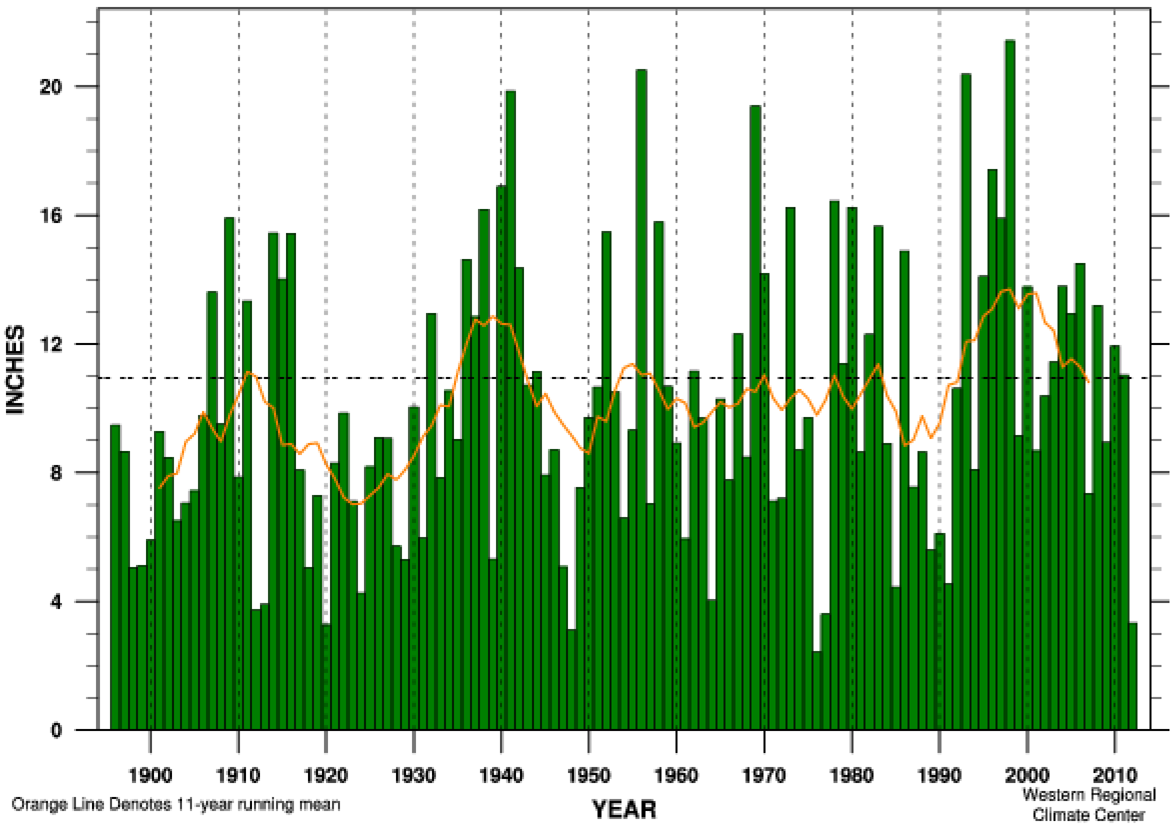
Linear Trend 1895-present		+ 0.87 ± 1.30 in.	(+ 18 ± 27%) per 100 yr	
Linear Trend 1949-present		+ 1.25 ± 3.66 in.	(+ 26 ± 77%) per 100 yr	
Linear Trend 1975-present		- 1.25 ± 8.67 in.	(- 26 ± 183%) per 100 yr	
Wettest Year		12.24 in. (258%)	in 1983	MEAN 4.73 in.
Driest Year		0.12 in. (2%)	in 2008	STDEV 2.61 in.
Mar-May	2012	6.57 in. (138%)		RANK 96 of 118



Linear Trend 1895-present	+ 1.17 ± 1.05 in.	(+ 31 ± 28%) per 100 yr			
Linear Trend 1949-present	- 1.01 ± 2.97 in.	(- 27 ± 80%) per 100 yr			
Linear Trend 1975-present	- 3.87 ± 6.73 in.	(- 104 ± 181%) per 100 yr			
Wettest Year	9.56 in. (257%)	in 1982		MEAN	3.71in.
Driest Year	0.18 in. (4%)	in 1929		STDEV	2.21in.
Sep-Nov 2011	2.50 in. (67%)			RANK	54 of 117

Sacramento-Delta Region

Precipitation Dec-Feb



Linear Trend 1895-present		+ 2.72 ± 2.26 in.	(+ 24 ± 20%) per 100 yr	
Linear Trend 1949-present		+ 1.52 ± 6.14 in.	(+ 13 ± 56%) per 100 yr	
Linear Trend 1975-present		+ 4.87 ± 14.74 in.	(+ 44 ± 134%) per 100 yr	
Wettest Year		21.42 in. (195%)	in 1998	MEAN 10.94 in.
Driest Year		2.42 in. (22%)	in 1976	STDEV 4.49 in.
Dec-Feb	2012	3.33 in. (30%)		RANK 4 of 117

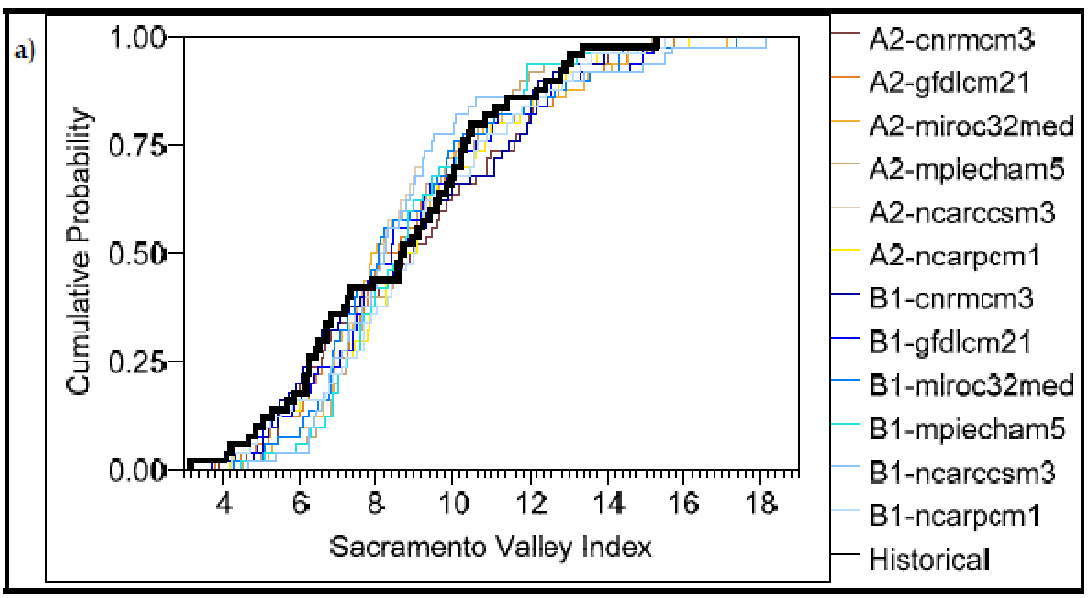
Projected Increases in the Frequency of Dry Water Years Under Climate Change

Many studies project an increase in the frequency and severity of droughts in California under climate change.

As part of the 3rd California Climate Change Assessment in 2012, the California Climate Change Center released a study by Sarah Null and Josh Viers at UC Davis, Water and Energy Sector Vulnerability to Climate Warming in the Sierra Nevada: Water Year Classification in Non-Stationary Climates.

The study used the six global climate models from the California Climate Assessment, and made projections under the SRES A2 (medium-high) and B1 (low) greenhouse gas emissions scenarios that were used in that assessment. (see Appendix.) The study usedthe same Variable Infiltration Capacity model that DWR uses for downscaling, with Bias-Corrected Spatial Disaggregation.

The main difference between the non-stationary study and modeling by the Department of Water Resources for assessments of climate change impacts on water supply, is that the non-stationary study did not correct model outputs to the historical hydrology. Instead, researchers ran the models without climate forcing, and compared the results to the historical hydrology. The graph below shows the cumulative probability of the different models compared with the observed 1951-2000 hydrology.



ANOVA and t-tests using a 95 percent confidence level found that results were not significantly different from historic hydrology. The graph and the statistical tests show that the models do a good job of capturing historic hydrology. This was one of the criteria for model selection.[5]

The results of the models under the A2 and B1 scenarios show a marked shift in climate. Most of the models show major increases in dry and critically dry years, and decreases in wet and below-normal

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[5] Climate Change Scenarios And Sea Level Rise Estimates for the California 2009 Climate Change Scenarios Assessment, A Paper From the California Climate Change Center. Cayan et. al. op. cit.

years. The histograms on the next page shows the changes in the frequency of water year types for the Sacramento Valley Index.

All of the models show a significant increase in dry and critically dry years by the latter half of the century, with a corresponding decrease in wet and above normal years. Many of the models also show an increase in dry and critically dry years in the first half.

The table below shows water year types, averaged over all six GCM models, for the two scenarios.

Table 6. Percentage of Years in Each Water Type by Modeled Time Period and Emissions Scenario (italicized values are percent change from historical period)

	SVI					
	1951-2000 (%)		2001-2050 (%)		2051-2099 (%)	
	A2	B1	A2	B1	A2	B1
Critical	8.7	8.3	11.3 *(2.7)*	6.7 *(-1.7)*	18.4 *(9.7)*	14.0 *(5.6)*
Dry	7.7	10.0	12.0 *(4.3)*	15.7 *(5.7)*	19.4 *(11.7)*	20.1 *(10.1)*
Below Normal	23.3	21.3	23.3 *(0.0)*	17.3 *(-4.0)*	18.7 *(-4.6)*	19.4 *(-1.9)*
Above Normal	21.0	22.7	16.7 *(-4.3)*	20.7 *(-2.0)*	12.9 *(-8.1)*	18.4 *(-4.3)*
Wet	39.3	37.7	36.7 *(-2.7)*	39.7 *(2.0)*	30.6 *(-8.7)*	28.2 *(-9.4)*

The medium-high emissions scenario (A2) projections showed dry and critically dry years in the Sacramento Valley increasing to 23% of all years between 2000 and 2050, and to 38% of all years in the latter half of the century. Under this scenario, the incidence of dry and critically dry years would more than double.

The projections also showed a decrease in wet years.

In the Sacramento Valley, the A2 projections showed wet and above normal years decreased to 53% of all years in 2000-2050, and to 41.5% of years by the latter half of the century.

The lower greenhouse gas emissions scenario (B1) showed similar but less dramatic shifts.

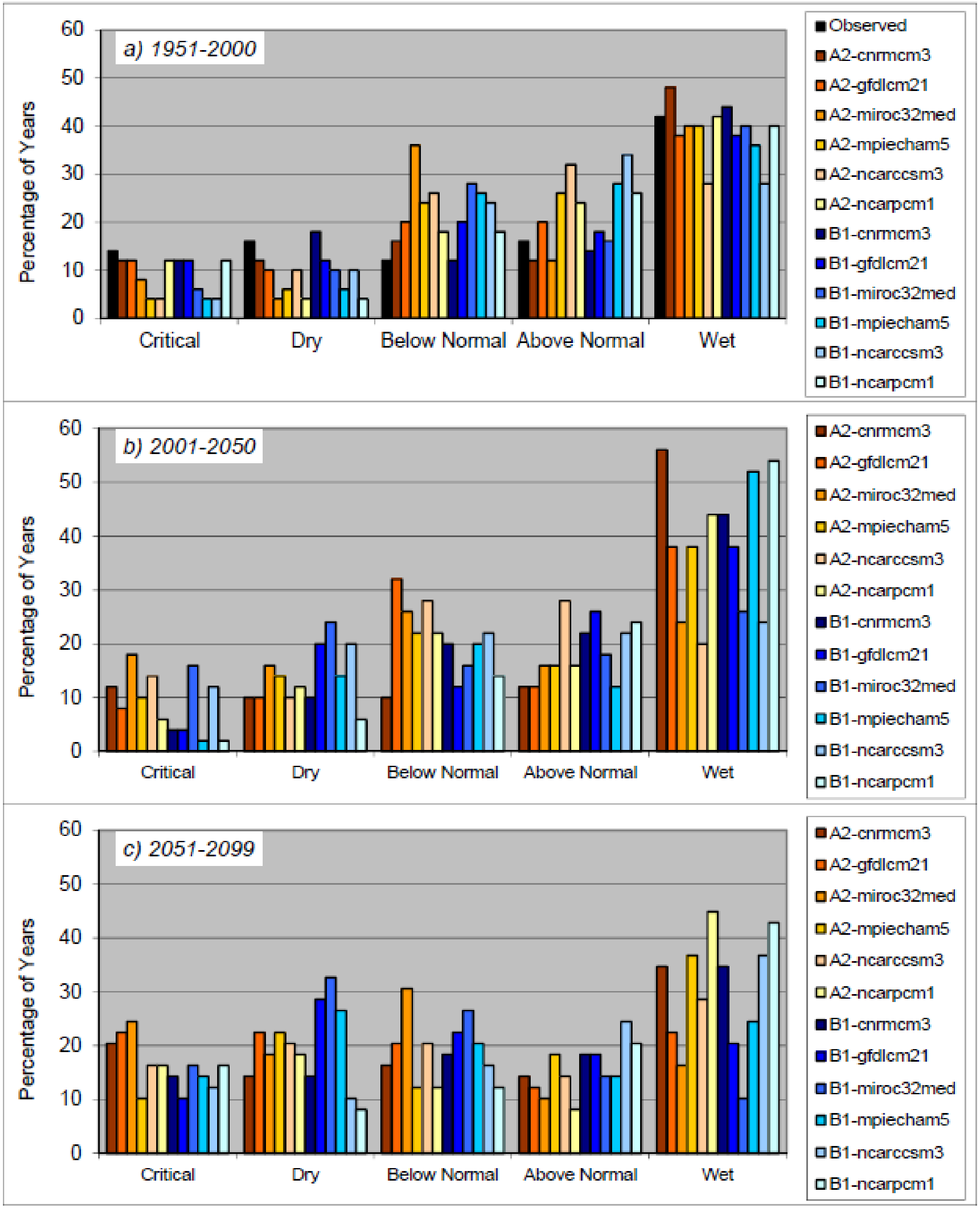


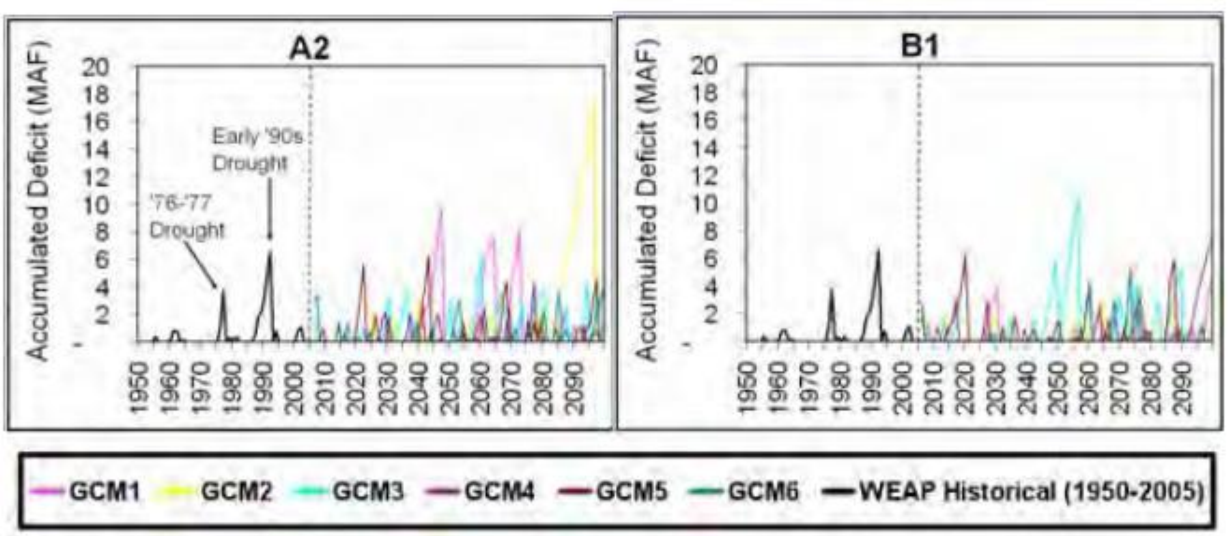
Figure 6. SVI Relative Frequency Histograms for (a) 1951-2000, (b) 2001-2050, and (c) 2051-2099

An earlier, study done by Brian Joyce, Vishal Mehta and David Purkey from the U.S. Center for the Stockholm Environmental Institute, Larry Dale from Lawrence Berkeley National Lab, and Michael Hanemann from the California Climate Center, was released as part of the second

California Climate Change Assessment in 2009, also showed significant increases in the frequency and severity of droughts. See Climate Change Impacts on Water Supply and Agricultural Water Management In California's Western San Joaquin Valley, and Potential Adaptation Strategies, August 2009.[6]

This study used the same set of twelve global climate models / climate change scenarios as the 2009 and 2012 California Climate Change assessment. The study used a application of the Water Evaluation and Planning (WEAP) system developed for the Sacramento River basin and Sacramento Delta. WEAP is an integrated rainfall / runoff and water resources modeling framework that was developed in Stockholm, and has been used for water resources planning around the world. WEAP has also been used in climate modeling for the 2009 California Water Plan, and is being used in preparing the 2013 California Water Plan.

WEAP has the advantage that it does not rely on perturbation of historical precipitation or runoff patterns for projections. This allows the model to capture major shifts in historical patterns. The study found marked increases in the frequency of droughts, and under the A2 scenario, a mega-drought towards the end of the century. The graph below shows the results for different models.



In sum, two recent studies using two different methods of downscaling showed major changes in the structure of droughts in California. Both indicated an increase in the frequency and severity of droughts. This information indicates that current stresses on the Delta due to over-export of unstored water are likely to increase with climate change.

[6] Climate Change Impacts on Water Supplies and Agricultural Water Management in the Western San Joaquin Valley and Possible Adaptation Strategies, Brian A. Joyce, Vishal K. Mehta, David R. Purkey, Larry L. Dale, and Michael Hanemann. California Climate Change Center, August 2009. Available at http://www.energy.ca.gov/2009publications/CEC-500-2009-051/CEC-500-2009-051-F.PDF

Potential reductions in runoff in Delta watersheds due to climate change

The US Geological Survey released a paper in February using the A2 scenario with the Global Fluid Dynamics Lab (GFDL) climate model. [7] The study was done by R.T. Hanson and other researchers at USGS in collaboration with Daniel Cayan, who oversaw the modeling for the California Climate Adaptation Strategy.

The paper uses the GFDL A2 scenario for predictions. This is a drier scenario which was used in the California Climate Adaptation Strategy. On the next page is a graph of predicted river flows in the Central Valley. The USGS models predict a 16-17% reduction in Sacramento River flows from 2020-2030 and 2040-2050, and a 34% reduction by 2080-2090. Similar reductions are predicted for the Tuolumne River.

[7] R.T. Hanson et. al., "A method for physically based model analysis of conjunctive use in response to potential climate changes," Feb 4, 2012. Available at http://ca.water.usgs.gov/projects/cvhm/Hanson_etal_2012_WRR.pdf.

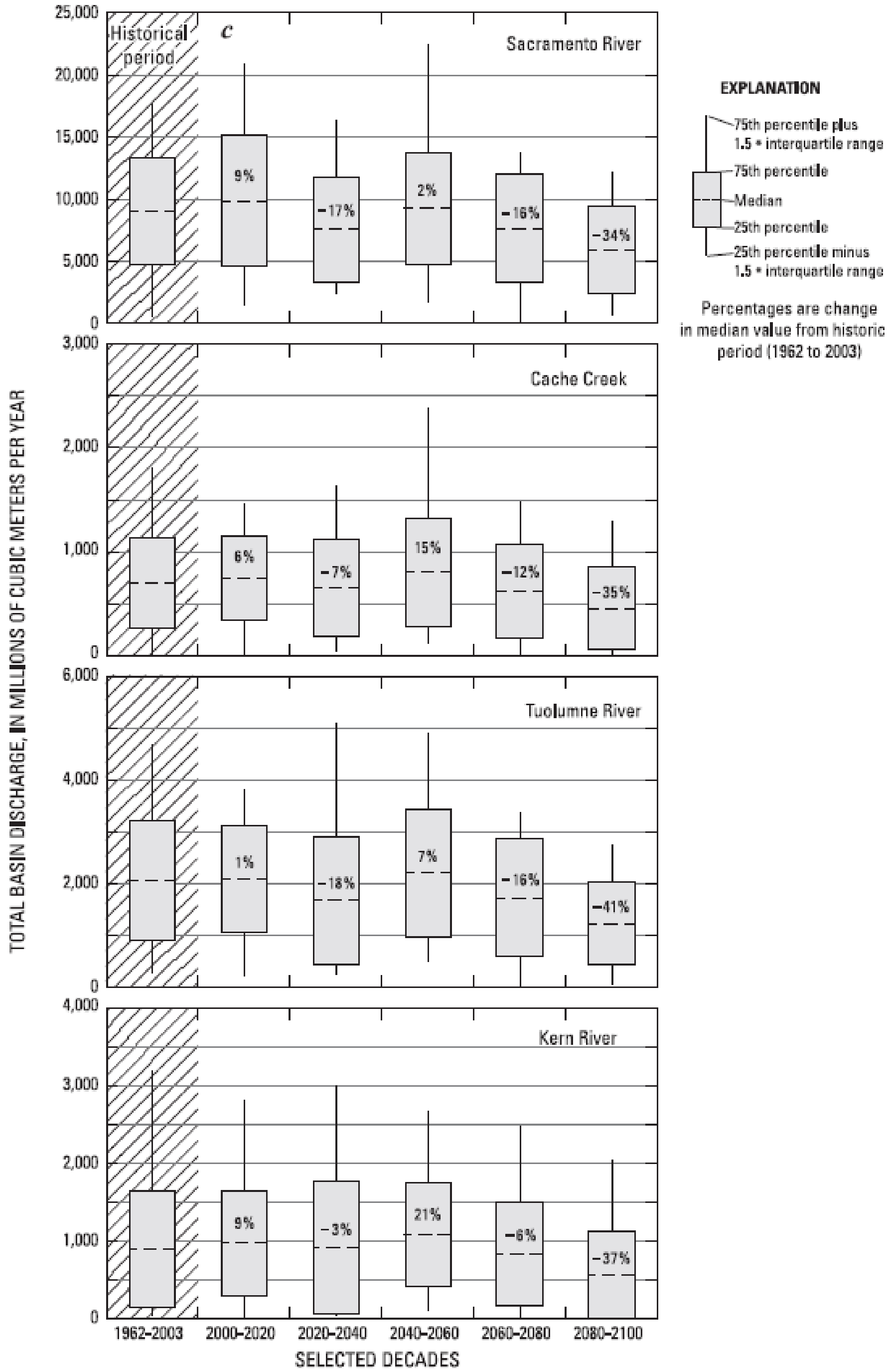


Figure 3. (continued)

The maps below show details of the reduction in river inflows from the USGS modeling. The different basins are color-coded, based on flow. There is a marked reduction in flows in all basins in the Central Valley by the end of the century.

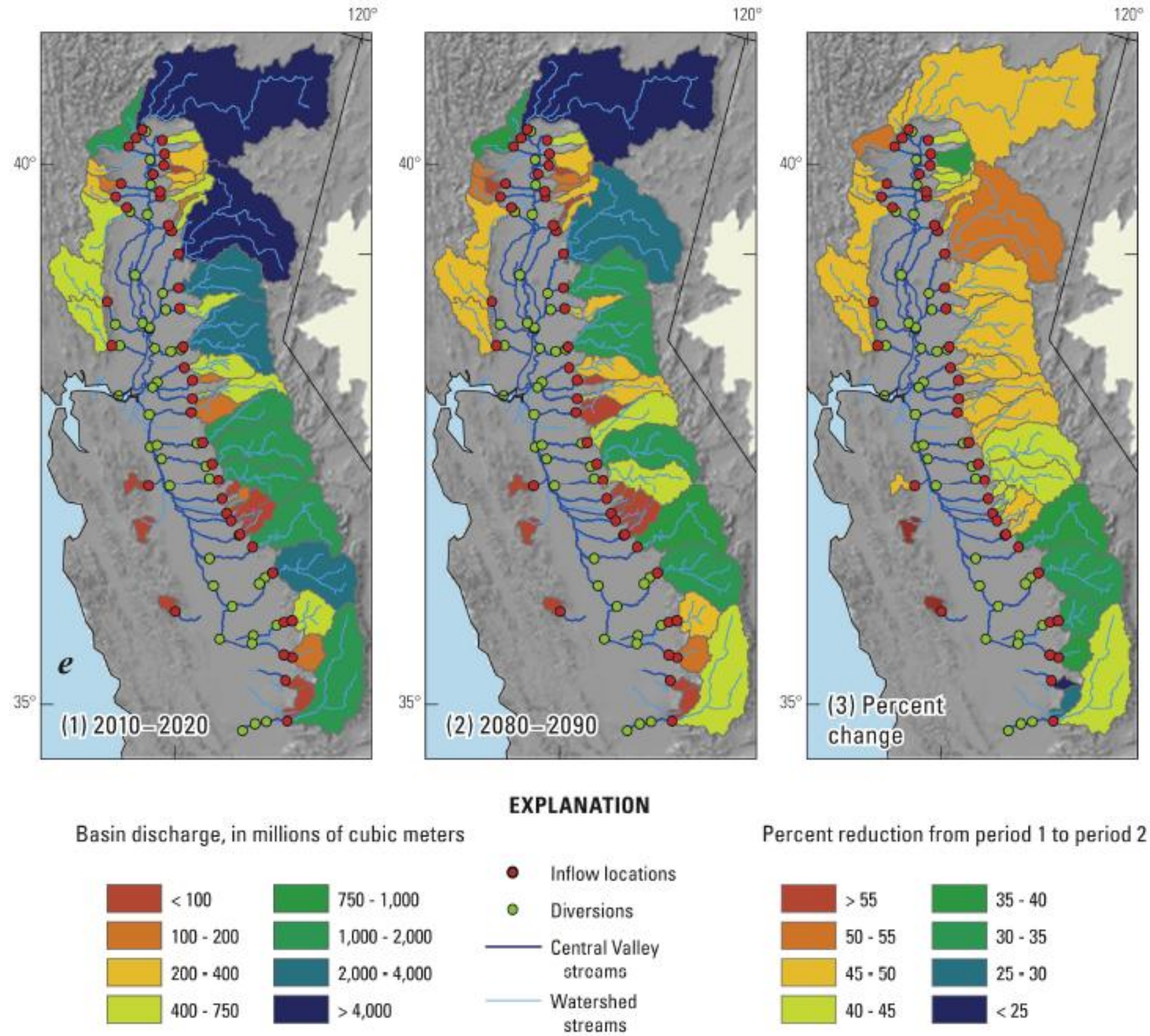


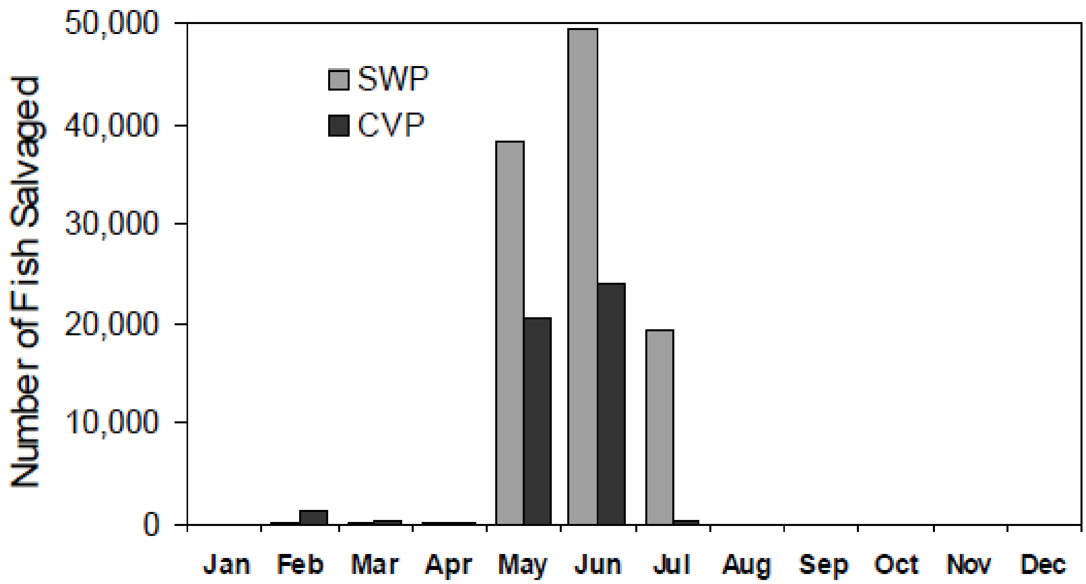
Figure 3. (continued)

Summer conditions leading to collapse of pelagic fish populations

Toxic algal blooms started in the Central Delta in 1999, and were associated with significant reductions in Delta inflows and outflows in late spring through fall. A study by Dr. Peggy Lehman of the Department of Water Resources found that large blooms of toxic algae in the

Delta appear to be linked with low flows and high air and water temperatures.[8] A more recent study linked the blooms to high water temperatures.[9]

Low flows also caused increased entrainment -- red light levels of Delta Smelt salvage were exceeded in May, June, and July of 1999.



Feyer, Sommer, and Slater[10] (2009) noted that threadfin shad exhibit a critical recruitment break between summer and fall, and speculated that there might be a tie to Microcystis blooms in the estuary:

> However, there did appear to be a complete "disconnect" between summer salvage density and FMT CPT, suggesting that factors occurring during the summer-to-fall transition might be one possible critical period. There are two factors in particular that are of concern for threadfin shad during this time period, dissolved oxygen and the toxic algae Microcystis aeruginosa, both of which occur in the center of threadfin shad distribution. Episodes of low dissolved oxygen concentration commonly occur in the San

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[8] Peggy Lehman et. Al., Initial impacts of Microcystis aeruginosa blooms on the aquatic food web in theSan Francisco Estuary, Hydrologica, 2010. Incorporated by reference.

[9] Mioni, C.E., Kudela, R.M., Baxa, D. (2012) Harmful cyanobacteria blooms and their toxins in Clear Lake and the Sacramento-San Joaquin Delta (California). Surface Water Ambient Monitoring Program (10-058-150). Final Report, March 31, 2012. Incorporated by reference.

[10] Feyer, Sommer, and Slater, Old school vs. new school: status of threadfin shad (Dorosoma petenense) five decades after its introduction to the Sacramento-San Joaquin Delta, San Francisco Estuary and Watershed Science, 7(1), 2009. Incorporated by reference.

Joaquin River and have been known to cause die-offs of threadfin shad. Such events are difficult to characterize and quantify but might be responsible in part for the sudden declines in abundance sometimes observed from one year to the next. In recent yearsthere have been dense blooms of M. aeruginosa geographically centered where threadfin shad are most abundant (Lehman and others 2008). The blooms also occur during the critical late summer/early fall when newly spawned fish are recruiting to the population (Lehman and others 2007).

Conclusion

Climate change is fundamentally shifting Sacramento River flows and Delta inflows, in a way that was not forseen when the original diversion permits in the Sacramento River and the Delta by the U.S. Bureau of Reclamation and the Department of Water Resources were issued by the State Water Rights Board in 1960 and 1967.

Not only has there been a significant reduction in precipitation in California in the spring and fall, as well as snowpack, there has been a maturity of water rights in the areas of origin. The assumption that there was unstored water available in the Delta for for export in the months of July, August, and September was always questionable, and it is likely that these developments have eliminated any surplus water in these months.

Rather than attempt to resovle these issues entirely by setting water quality targets for these months, which involves a great deal of uncertainty, given the range of future scenarios due to climate change, it would be more protective of the rights of the areas of origin to bar exports of unstored water in the Delta for those months in which studies show that it has not been available for the past two decades.

This assures the areas of origin that water exported during these times will actually be stored water.

Water quality targets can then focus on what quantities of stored water that will leave necessary bypass flows in the Sacramento River and the Delta.

Appendix. Tables of water remaining in the Delta. From the North Delta Water Agency.

Table B – Water Remaining in the Delta after Satisfaction of all Pre-1927 Appropriative and Other Rights

(Before water quality requirements are satisfied)[1]

(In thousands of acre-feet)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1924[2]	511	103	0	0	0	0	215	829
1925	3,950	2,980	1,004	0	0	101	386	8,421
1926	3,816	1,091	46	0	0	62	310	5,325
1927	5,199	3,122	1,862	116	0	156	432	10,887
1928	4,024	1,771	254	0	0	128	354	6,531
1929	1,076	987	273	0	0	70	282	2,688
1930	1,953	1,202	370	0	0	170	412	4,107
1931[2]	410	76	0	0	0	0	154	640
1932[2]	1,897	2,687	1,768	206	0	36	231	6,825
1933[2]	1,324	1,056	891	0	0	18	250	3,539
1934[2]	927	214	0	0	0	0	188	1,329
1935	6,629	3,826	1,894	0	0	117	421	12,887
1936	3,522	2,703	1,486	25	0	141	342	8,219
1937	3,990	3,537	1,593	4	0	86	457	9,667
1938	7,122	6,688	4,584	1,069	30	291	602	20,386
1939	1,132	356	0	0	19	63	292	1,862
1940	7,142	2,660	1,045	0	0	204	406	11,457
1941	6,479	4,772	2,557	636	0	195	471	15,110
1942	4,894	4,141	3,163	614	0	246	536	13,594
1943	4,231	2,686	1,425	21	0	172	501	9,036
1944	1,362	1,559	496	0	0	122	374	3,913
1945	2,412	2,608	1,340	41	0	167	548	7,116
1946	2,536	2,423	650	0	0	197	404	6,210
1947	1,577	421	213	0	0	126	535	2,872
1948	3,871	3,417	2,200	0	0	185	455	10,128
1949	2,380	1,648	240	0	0	104	240	4,612
1950	3,010	2,112	922	0	0	155	778	6,977
1951	1,915	2,141	358	0	0	228	518	5,160
1952	6,569	6,538	3,630	668	0	361	536	18,302
1953	2,240	2,591	2,033	193	0	350	551	7,958
1954	4,078	1,845	312	0	0	275	497	7,007
Total	**102,178**	**73,961**	**36,609**	**3,593**	**49**	**4,526**	**12,678**	**233,594**
Average	**3,296**	**2,386**	**1,181**	**116**	**2**	**146**	**409**	**7,535**
Number of Deficient Months	**0**	**0**	**4**	**20**	**29**	**3**	**0**	**56**

[1] Includes satisfaction of all assumed Riparian and Pre-1927 Appropriative and Other Rights of local water users along the Sacramento River above Sacramento and in the Delta Uplands and Lowlands to the extent of the available supply and before water quality requirements are met.

[2] Denotes Critical Year.

Table C – Water Remaining in the Delta after Satisfaction of all Pre-1938 Appropriative and Other Rights

(Before water quality requirements are satisfied)[1]

(In thousands of acre-feet)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1924[2]	376	100	0	0	0	0	78	554
1925	3,167	2,612	806	0	0	29	220	6,834
1926	3,322	888	39	0	0	13	157	4,419
1927	4,196	2,718	1,642	98	0	63	268	8,985
1928	3,454	1,443	183	0	0	49	202	5,331
1929	704	763	232	0	0	43	152	1,894
1930	1,559	935	351	0	0	106	260	3,211
1931[2]	230	67	0	0	0	0	33	330
1932[2]	1,505	2,335	1,652	201	0	5	100	5,798
1933[2]	864	755	766	0	0	3	131	2,519
1934[2]	636	90	0	0	0	0	67	793
1935	5,446	3,328	1,774	0	0	56	270	10,874
1936	3,047	2,412	1,308	20	0	84	202	7,073
1937	3,136	3,173	1,383	0	0	44	304	8,040
1938	6,505	6,326	4,177	966	36	158	432	18,600
1939	832	262	0	0	0	22	152	1,268
1940	6,525	2,316	933	0	0	121	242	10,137
1941	5,360	4,410	2,169	523	0	87	302	12,851
1942	4,029	3,528	2,743	512	0	123	317	11,252
1943	3,518	2,280	1,169	0	0	66	298	7,331
1944	1,022	1,289	395	0	0	31	209	2,946
1945	1,970	2,234	1,151	36	0	104	377	5,872
1946	1,999	2,082	551	0	0	92	242	4,966
1947	1,160	350	26	0	0	30	364	1,930
1948	3,000	3,055	1,778	0	0	49	290	8,172
1949	1,796	1,317	204	0	0	21	99	3,437
1950	2,422	1,817	888	0	0	87	390	5,604
1951	1,440	1,723	295	0	0	121	348	3,927
1952	5,799	6,127	3,280	563	0	168	366	16,303
1953	1,639	2,010	1,594	111	0	167	380	5,901
1954	3,155	1,483	156	0	0	111	326	5,231
Total	**83,813**	**64,228**	**31,645**	**3,030**	**36**	**2,053**	**7,578**	**192,383**
Average	**2,704**	**2,072**	**1,021**	**98**	**1**	**66**	**244**	**6,206**
Number of Deficient Months	**0**	**0**	**4**	**22**	**30**	**3**	**0**	**59**

[1] Includes satisfaction of all assumed Riparian, Pre-1927, 1927-38 Appropriative and Other Rights of local water users along the Sacramento River above Sacramento and in the Delta Uplands and Lowlands, and the assumed 1927 Right of the United States at Shasta Dam to the extent of the available supply and before water quality requirements are met.

[2] Denotes Critical Year.

Table D – Water Remaining in the Delta after Satisfaction of all Pre-1954 Appropriative and Other Rights

(Before water quality requirements are satisfied)[1]

(In thousands of acre-feet)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1924[2]	87	0	0	0	0	0	0	87
1925	2,980	2,501	639	0	0	0	25	6,145
1926	3,135	708	0	0	0	0	0	3,843
1927	4,009	2,665	1,497	0	0	0	71	8,242
1928	3,274	1,344	0	0	0	0	0	4,618
1929	524	604	0	0	0	0	0	1,128
1930	1,372	817	5	0	0	0	51	2,245
1931[2]	0	0	0	0	0	0	0	0
1932[2]	1,330	2,241	1,403	0	0	0	0	4,974
1933[2]	677	651	526	0	0	0	0	1,854
1934[2]	463	0	0	0	0	0	0	463
1935	5,259	3,213	1,529	0	0	0	0	10,001
1936	2,860	2,306	1,121	0	0	0	60	6,347
1937	2,949	3,078	1,228	0	0	0	0	7,255
1938	6,325	6,231	4,112	0	0	0	96	16,764
1939	661	0	0	699	0	0	241	1,601
1940	6,345	2,213	680	0	0	0	45	9,283
1941	5,180	4,315	2,102	266	0	0	110	11,973
1942	3,842	3,413	2,666	244	0	0	88	10,253
1943	3,331	2,165	1,060	0	0	0	71	6,627
1944	867	1,173	131	0	0	0	13	2,184
1945	1,783	2,143	975	0	0	0	187	5,088
1946	1,819	1,986	285	0	0	0	43	4,133
1947	973	38	0	0	0	0	174	1,185
1948	2,820	2,960	1,728	0	0	0	94	7,602
1949	1,609	1,219	0	0	0	0	0	2,828
1950	2,235	1,712	557	0	0	0	200	4,704
1951	1,253	1,608	0	0	0	0	157	3,018
1952	5,619	6,032	3,209	298	0	2	175	15,335
1953	1,452	1,895	1,523	0	0	0	190	5,060
1954	2,975	1,388	0	0	0	0	136	4,499
Total	**78,008**	**60,619**	**26,976**	**1,507**	**0**	**2**	**2,227**	**169,339**
Average	**2,516**	**1,955**	**870**	**49**	**0**	**0**	**72**	**5,463**
Number of Deficient Months	**1**	**4**	**11**	**27**	**31**	**30**	**11**	**115**

[1] Includes satisfaction of all assumed Riparian and Appropriative and Other Rights water users along the Sacramento River above Sacramento and in the Delta Uplands and Lowlands with priorities prior to January 1, 1954, including the assumed 1927 and 1938 Rights of the United States at Shasta Dam and in the Delta, to the extent of the available supply before water quality requirements are met.

[2] Denotes Critical Year.

Table E – Water Remaining in the Delta after Satisfaction of all Pre-1955 Appropriative and Other Rights

(Before water quality requirements are satisfied)[1]

(In thousands of acre-feet)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1924[2]	114	0	0	0	0	0	0	114
1925	3,030	2,446	555	0	0	0	11	6,042
1926	3,185	651	0	0	0	0	0	3,836
1927	4,059	2,552	1,413	0	0	0	34	8,058
1928	3,316	1,288	0	0	0	0	0	4,604
1929	574	547	0	0	0	0	0	1,121
1930	1,422	761	0	0	0	0	24	2,207
1931[2]	30	0	0	0	0	0	0	30
1932[2]	1,375	2,181	1,319	0	0	0	0	4,875
1933[2]	727	601	442	0	0	0	0	1,770
1934[2]	505	0	0	0	0	0	0	505
1935	5,309	3,163	1,445	0	0	0	28	9,945
1936	2,910	2,256	1,037	0	0	0	0	6,203
1937	2,999	3,007	1,144	0	0	0	55	7,205
1938	6,367	6,160	4,036	590	0	0	193	17,346
1939	701	0	0	0	0	0	0	701
1940	6,387	2,158	596	0	0	0	21	9,162
1941	5,222	4,244	2,030	157	0	0	65	11,718
1942	3,892	3,363	2,589	135	0	0	79	10,058
1943	3,381	2,115	976	0	0	0	60	6,532
1944	891	1,118	53	0	0	0	5	2,067
1945	1,833	2,080	891	0	0	0	139	4,943
1946	1,861	1,928	201	0	0	0	20	4,010
1947	1,023	9	0	0	0	0	126	1,158
1948	2,862	2,889	1,619	0	0	0	51	7,421
1949	1,659	1,163	0	0	0	0	0	2,822
1950	2,285	1,663	473	0	0	0	152	4,573
1951	1,305	1,563	0	0	0	0	111	2,979
1952	5,661	5,961	3,140	56	0	0	127	14,945
1953	1,502	1,845	1,452	133	0	0	142	5,074
1954	3,017	1,317	0	0	0	0	88	4,422
Total	**79,404**	**59,029**	**25,411**	**1,071**	**0**	**0**	**1,531**	**166,446**
Average	**2,561**	**1,904**	**820**	**35**	**0**	**0**	**49**	**5,369**
Number of Deficient Months	**0**	**4**	**12**	**26**	**31**	**31**	**11**	**115**

[1] Includes satisfaction of all assumed water rights of local water users along the Sacramento River above Sacramento and in the Delta Uplands and Lowlands, and the United States at Shasta Dam and in the Delta with priorities prior to January 1, 1955 to the extent of the available supply before water quality requirements are met.

[2] Denotes Critical Year.